INVESTIGATION OF ROTOR POSITION DETECTION SCHEMES FOR PMSM DRIVES BASED ON ANALYTICAL MACHINE MODEL INCORPORATING NONLINEAR SALIENCIES

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CERTIFICATE OF AUTHORSHIP/ORIGINALITY

I certify that the work in this thesis has not previously been submitted for a degree nor has it been submitted as part of requirements for a degree except as fully acknowledged within the text.

I also certify that the thesis has been written by me. Any help that I have received in my research work and the preparation of the thesis itself has been acknowledged. In addition, I certify that all information sources and literature used are indicated in the thesis.

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ABSTRACT

This thesis presents the essential and new improvements of the machine modelling and drive-strategies for permanent magnet synchronous machines (PMSMs), including the rotor position sensorless drive schemes. Many important issues about PMSM drive schemes, from the modelling to drive design have been investigated from the machine model point of view. A comprehensive PMSM model incorporating both structural and magnetic saturation saliencies has been developed and expressed numerically and analytically. Highly efficient rotor position detection method has been developed based on the new machine model.

The traditional mathematical model of PMSM is investigated at the beginning of this thesis for the conventional PMSM drive schemes, including six-step control, field oriented control (FOC) and direct torque control (DTC). The fundamental principles and improvements of the drives are summarized based on the machine model. Performance comparison is conducted for different schemes and an improved DTC scheme is developed.

PMSM drive without rotor position sensor, or so called sensorless drive, is a desired feature for the electrical servo systems and automotive applications. The lack of accurate nonlinear machine model is the bottle neck for highly efficient sensorless drive development. Experiment trial and error attempts have to be employed to design rotor position detection schemes. On the other hand, there is not a comprehensive machine model to assess the sensorless drive performance.

The inaccuracies associated with the conventional PMSM model have been discussed in this thesis. The saliencies in PMSM utilized for rotor position tracking are classified as two types, the structural saliency and the magnetic saturation saliency. The nonlinear saturation saliency cannot be modelled in the conventional PMSM model. However, it is essential for the rotor position estimation, especially the initial rotor position detection. A composite function is designed to express the inductances of PMSM, incorporating the nonlinear saturation saliency. Experimentally collected inductance data are used to regress the parameter matrix and a numerical PMSM model is developed.

It is then proved that the structural and saturation saliencies can be decoupled analytically and expressed separately. The concepts, structural saliency ratio and saturation saliency ratio are defined to indicate the magnetic saliency in PMSMs. The analytical mathematic machine model incorporates the nonlinear behaviour of the magnetic field of PMSMs. The proposed model is validated by the experimentally collected data.

Based on the developed analytical nonlinear machine model, a DC voltage pulse injection based initial rotor position detection scheme is designed and implemented. Thanks to the comprehensive machine model, improved injection scheme is designed to minimize the rotor vibration and increase the estimation speed. Simulation and experiment of the novel detection method are conducted to verify the estimation accuracy.

Finally the proposed model is applied to analyse the sensorless drive schemes for PMSMs. The investigation focuses on high frequency signal injection based sensorless methods. A new injection method is proposed based on the machine model, in which the carrier signal is injected on a fixed stator spatial direction. The proposed sensorless method and other reported sensorless schemes are compared based on both machine model and simulation. According to the nonlinear machine model, generalized indicators are defined to express the drive performance, computing cost and estimation efficiency, which provide a comprehensive assessment for sensorless drive schemes of PMSM.

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